Skinner Lake Water Quality Analysis
1990–91 Assessment of Wetland Reconstruction

Project Final Report
November, 1991

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Executive Summary

Skinner Lake of Noble County, Indiana is one of many lakes of glacial origin dotting the landscape of Northern Indiana. It is impacted by many natural and made-made factors that are contributing to its rapid eutrophication. The reconstructed sedimentation basin, completed December 27, 1990, on its primary tributary is slowing down the input of phosphorus into the lake. This limiting nutrient for growth, however, is presently found at values approaching ten times those levels found in previous studies. Nitrogen, another valuable nutrient, appears to have levels elevated as the result of the sedimentation basin reconstruction. Growth of nuisance bluegreen algal populations are evidenced throughout the year long study in lake water. Continued eutrophication is anticipated.

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Introduction

Skinner Lake in Noble County, Indiana is one of several lakes targeted by the Indiana Department of Natural Resources T by 2000 Lake Enhancement Program. In 1978-79 the lake was investigated as an EPA Clean Lakes Program demonstration project, and a management plan was developed. To reverse eutrophication the 1980-82 management plan recommendations for the lake and its watershed were implemented by the US EPA Clean Lakes Program in cooperation with the US Soil Conservation Service. The sedimentation basin was originally constructed during the winter of 1981-82 and was completed by spring 1982. Data were collected to assess the effectiveness of various land management strategies on the lake during 1978-82 by the Noble County Soil and Water Conservation District with assistance by the US EPA and Michigan State University. The results of this project are contained within the report entitled "Impact of Land Treatment on the Restoration of Skinner Lake, Noble County, Indiana" (6).

Approximately 10 years later a reconstruction of the Rimmell wetlands has been completed. Reconstruction of the sedimentation basin began in mid-November 1990 and was completed by December 27, 1990. It was within the few months immediately preceding, during the reconstruction, and immediately following this project that various water chemical, physical, and biological parameters were monitored. The intent of the project was to measure selected parameters on the Rimmell ditch, above the reconstructed sediment trap, after the sediment trap at the entry to Skinner Lake, and at one in-lake station as well. In addition to assessing the impact the reconstructed wetland has had on the water quality of the in-flow stream and present lake conditions, we shall compare, where possible, lake and in-flow stream parameters with those gathered in the 1979-82 study conducted by Michigan State University.

Data collected in this study will also allow the calculation of the Bonhomme Eutrophication Index as proposed by Senft and Torke in the Indiana Lake Classification System and Management Plan (5). Carlson's trophic state index (TSI) is also determined (2).

This project has been sponsored by several agencies within the state and region. The grant was awarded by the Noble County Soil and Water Conservation district under the chairmanship of Mr. Allan Osterlund and subsequently Mr. Ed Harper. Mr. Wayne Stanger and Mr. David Hague provided perspectives on past actions and present practices being employed by local residents/farmers. The Skinner Lake Homeowners Association provided access for in-lake sampling. Mr. Galen Darr and Mr. Keith Kline were very instrumental in this aspect of the project. Region 5 EPA funds were also identified to support this project. Managerial, technical, and financial assistance was provided by the Indiana Department of Natural Resources. Mr. Paul Glander and Ms. Kelly Boatman aided us on many occasions in planning the project and helping make contacts with local and state officials active in the T by 2000 Lake Enhancement Program, of which this project is a part. Finally, the support of Ball State University is gratefully acknowledged. It is through the efforts of Biology faculty who provided insightful comments and questions to the coordinators, Biology staff who supplied both clerical and technical support in the preparation of this manuscript, staff of Office of Research and Sponsored Programs who helped formulate budgets and supportive materials, and finally to the Office of Contracts and Grants at Ball State University who provided prompt and courteous updates of budgetary matters to keep the project moving forward.

formulate budgets and supportive materials, and finally to the Office of Contracts and Grants at Ball State University who provided prompt and courteous updates of budgetary matters to keep the project moving forward.

The work of this project has been made possible through efforts of many at Ball State University. Indeed, the project objectives have been enhanced due to the activities of many graduate and undergraduate students having interest in aquatic ecology/biology. The insight and knowledge of my colleague, Byron Torke, has been invaluable in problem solving and explaining apparent inconsistencies in data obtained. His field expertise and leadership made sampling routine and safe. Secondly, research assistant, Sheldon Gurney, provided coordination of field equipment and field expertise in both lake and stream sampling. In addition, he was responsible for maintenance and repair of equipment and data collection from field and laboratory. Other graduate students active in this project were Linda Airey and Mike Mayfield examining algal and macrophyte populations, respectively, under the direction of Byron Torke; Wayne Evans and Chuck Goff examining atrazine and bacterial interactions from lake environments under the direction of Carl Warnes; and David Bauman for spread sheet manipulation and graphing capabilities under the direction of Carl Warnes. Under Byron Torke's sponsorship, undergraduate Gretchen Miller examined the zooplankton populations of Skinner Lake. Finally, the encouragement of colleagues such as Tom McComish and Don Hendrickson have made this project more enjoyable, manageable, and productive.

Methods

Sample Collection

Both in-lake and tributary samples were collected on 16 occasions during 1990-91. Samples were collected at one in-lake site corresponding to the deepest water column and two tributary sites (Appendix X). Samples were collected monthly during September through April with two samples being collected during the remaining four months of May, June, July and August. Sampling began August 27, 1990 and concluded on August 8, 1991.

In-lake sample collection was taken at a single site corresponding to the deepest point in the lake. This site was also sampled during the 1979-82 study conducted by Michigan State. Samples were collected from a pontoon or flat bottom boat, supplied by homeowners, or through ice cover. Composite lake samples were taken from the upper and lower pelagial strata for water chemistry, algal assays, and chlorophyll a analysis. Two hundred fifty ml of water were taken from the four depths of 8,7,6, and 5 meters for the lower pelagial sample (labeled hypolimnion in the present study). Identical volumes were taken from 4,3,2 and 1 meter depths to comprise the upper pelagial sample and labeled epilimnion. (The lake thermocline, when present, fluctuated between 3.5 and 4 meters depth.) All samples were collected with a 9 liter vertical Van Dorn water sampler. After collection the sampler was inverted several times to mix the contents of the Van Dorn. One liter composite samples were collected for chemical analysis (with and without H_2SO_4 preservative), for algal analysis preserved with 10 ml Lugol's solution, in opaque brown plastic bottles and plastic bottles unpreserved for alkalinity. One liter bottles covered with aluminum foil were filled with water (at 1-5 meter depths) for chlorophyll a analysis. All were stored on ice in transit. On most occasions vertical net tows were taken for zooplankton analysis. Samples were rinsed from a 20 cm diameter student net and placed in small jars containing 5% formalin for preservation of the sample. During the summer months, water samples were taken at the thermocline (3.5 m) and surface using a J-Z Bacteriological water sampler. This instrument permits a sterile sample of water to be taken at discrete depths without contamination of water from other depths.

Two sites were examined on the major tributary to Skinner Lake. The Rimmell tributary was sampled above and below the reconstructed wetland. The same water chemistry was examined at both these sites to assess the impact of the reconstructed wetland on nutrient loading to the lake. No samples were prepared for chlorophyll a, algal, zooplankton or bacteriological examination. Samples were taken from the middle of the stream using an extension pole sample retriever when available. Other times grab samples were taken at stream's edge.

All samples were delivered to the laboratory for processing, in all instances, within 5 hours of collection. Usual delivery was 3-3 1/2 hours following collection.

On site Analysis

Several physical and chemical parameters were monitored the day of collection. These were pH, dissolved oxygen (DO), conductivity, temperature, and Secchi disk transparency.

A YSI DO meter (model #58) was used for monitoring both DO and temperature. pH values were monitored with a Beckman Model Phi 21 or a Corning model 3D pH meter. Conductivity values were determined using a YSI model 33 conductivity meter. Conductivity and pH were determined from samples brought to the surface. Temperature and DO were determined in situ. Secchi disk transparency, a physical parameter highly correlated with algal biomass, was determined.

Sample Processing

Analytical methods used in this study are outlined in "Methods for the Chemical Analysis of Water and Wastes" (3), identified by EPA#, and "Standard Methods for the Examination of Water and Wastewater", identified by SM#.(1)

Total and total reactive phosphorus (EPA 365.2)

A colorimetric method in which phosphorus formed an antimony-phospho-molybdate complex was used. The addition of ascorbic acid forms an intense blue color that is proportional to reactive(ortho) phosphorus concentrations. Total phosphorus was determined via acid hydrolysis of the unfiltered sample. Values are referred to as total phophorus instead of total hydrolyzable phosphorus. Those reported from the laboratory as total reactive phosphorus are referred to here as soluble or ortho phosphorus as measured by direct colorimetric analysis of unfiltered samples. Dissolved orthophosphates were not subtracted from this value. Values obtained from the laboratory were divided by 3.06 in order to convert total phosphate to phosphorus.

Total Kjeldahl nitrogen - TKN (EPA 351.3)

Samples were processed by heating in the presence of H_2SO_4, K_2SO_4 and $HgSO_4$ until SO_3 fumes were obtained and the solution became colorless. After cooling the residue, it was made alkaline with hydroxide-thiosulfate solution, followed by distillation and the resulting ammonia was determined by titration. This method used the Teccator automated equipment.

Nitrate-Nitrite and Nitrite (EPA 353.3, 354.1)

Nitrate-nitrite nitrogen was analyzed for by the cadmium reduction method. Filtered samples were passed through a Cu-Cd column to convert nitrate to nitrite. Total nitrate-nitrite N was determined by diazotizing with sulfanilimide and coupling with N-(1-naphthyl)-ethylenediamine dichloride to form a colored azo dye and measured spectrophotometrically. Total nitrite N was determined as above but without the cadmium reduction step.

Ammonia (EPA 350.3)

A selective ion electrode method was used to determine ammonia in samples. The ammonia was determined potentiometrically using an ammonia electrode and a pH meter with an expanded millivolt scale.

Total Dissolved Solids (TDS)/Total Suspended Solids (TSS) (EPA 160.1, 160.2)

TDS was measured by filtering the sample through a glass fiber filter and evaporating the filtrate to dryness at 180^{o}C. Weight was determined as mg/l.

TSS was measured by filtering the sample through a glass fiber filter and weighing the filter after oven drying at 103-105°C for 1 hour. The difference in filter weight before and after the sample processing was expressed in mg/l.

Alkalinity (SM2320)

Alkalinity is a function of the concentration of carbonate, bicarbonate, hydroxide, and other ions in a water sample which shift the pH toward the alkaline side of neutrality. The titrametric method used brom cresol green (pH 4.5) and 0.02 N sulfuric acid and was expressed as mg Calcium carbonate per liter.

Chlorophyll a (SM 10200H)

Chlorophyll a is a significant method used to examine biomass of phytoplankton. It is the major light-trapping pigment in photosynthetic organisms. Pigments were extracted from water samples and filtered. Filtered samples were examined spectrophotometrically for absorbance and *chlorophyll a* determination.

Algal species composition, density, and volume

A 1000 ml sample preserved with 10 ml Lugol's solution was gently shaken to evenly distribute the algae sample. 100 ml of this sample was then poured into a 100 ml graduated cylinder (covered with parafilm) and was allowed to settle for at least 24 hours. The upper portion was decanted and the remaining 40 mls of concentrated algae placed in an Ultrasonic Cleaner to separate colonies of *Microcystis* in order to count the individual cells.

After the ultrasound was applied to the samples they were transferred into sedimentation chambers and allowed to settle again for 12 hours. These sedimentation chambers hold 20 mls with a sediment viewing area of 491 mm^2. The sedimentation chamber was then scanned on the inverted microscope at 100X magnification to make algal identifications.

At 200X, the Whipple ocular micrometer was used to count the number of cells of *Microcystis* in the grid of the sedimentation chamber. The length and width of *Oscillatoria* trichomes were measured and the volume was determined at 200X. Finally, the total number of *Oscillatoria* strands that were observed on the 100 square area of the Whipple ocular micrometer were counted to determine the number of strands in the 1000 ml sample. Cell numbers were converted to biomass by the cell volume method devised by Nauwerk(7). Seasonal variations in species composition and biomass were determined.

Zooplankton

Zooplankton populations were sampled biweekly in warm months (May-August) and monthly in cold months (November-April). Samples were collected by making a vertical haul with a 20 cm. diameter Student plankton net (mesh aper.=64u) from the deepest point in the lake (ca 8.5 M). Samples were preserved in 5% formalin, subsampled with a 1 ml. Stempel pipette and counts were made in a Gannon counting tray under a dissecting microscope. In addition, the entire sample was examined for rare species.

Bacteriological

Both heterotrophic and chitinolytic bacteria were enumerated during the summer months. Standard Plate Count Agar (PCA) and chitin mineral salts agar (CMSA) were inoculated with dilutions of lake water. Plates were inoculated in duplicate for each dilution and incubated at room temperature (22°C) for 2 days (PCA) or 5 days (CMSA). Total heterotrophs were determined on PCA while the chitinolytic population was determined by enumerating colonies showing a zone of hydrolysis or CMSA.

Herbicide/Pesticide Scan (EPA 525)

Using Gas Chromatography/Mass Spectroscopy equipment, water samples collected on 6-12-91 were examined for various pesticides, herbicides, and semi-volatiles. Concentrations above detection limits were not found in grab samples taken at the Rimmell out sampling site on this tributary to Skinner Lake.

Macrophyte Analysis

On-site observations by the investigators provide a vegetational map of macrophytes found at the lake edge and littoral zones. Aerial photography provided corroboration of ground assessment. The on site assessment was made July 24 and aerial photographs were taken on August 1, 1991. This was accomplished by sampling the lake both from the shoreline and by boat.

Results

The four objectives of this project, namely to monitor water quality for 1 calendar year; compare, whenever possible, water quality now with that reported in the 1979-82 study of Michigan State University; evaluate, when possible, the effectiveness of the newly reconstructed sediment trap; and, finally, assess the trophic state of the lake, will be presented by first examining physical data of the lake and Rimmell tributary.

The morphometric parameters of Skinner Lake are presented elsewhere (5,6). Values for temperature and DO taken at the deep station in Skinner Lake are presented in figures 1 and 2, respectively. (Actual values are included in appendices I and II.) A thermocline is evident during most of the warmer months with stratification beginning in May and maintaining itself through August of the present study. In the Autumn of 1990 the thermocline disappeared by October as the result of lake mixing (fig. 1). Dissolved oxygen was depleted during most of the summer months and remained so through the October sampling of 1990 (fig. 2).

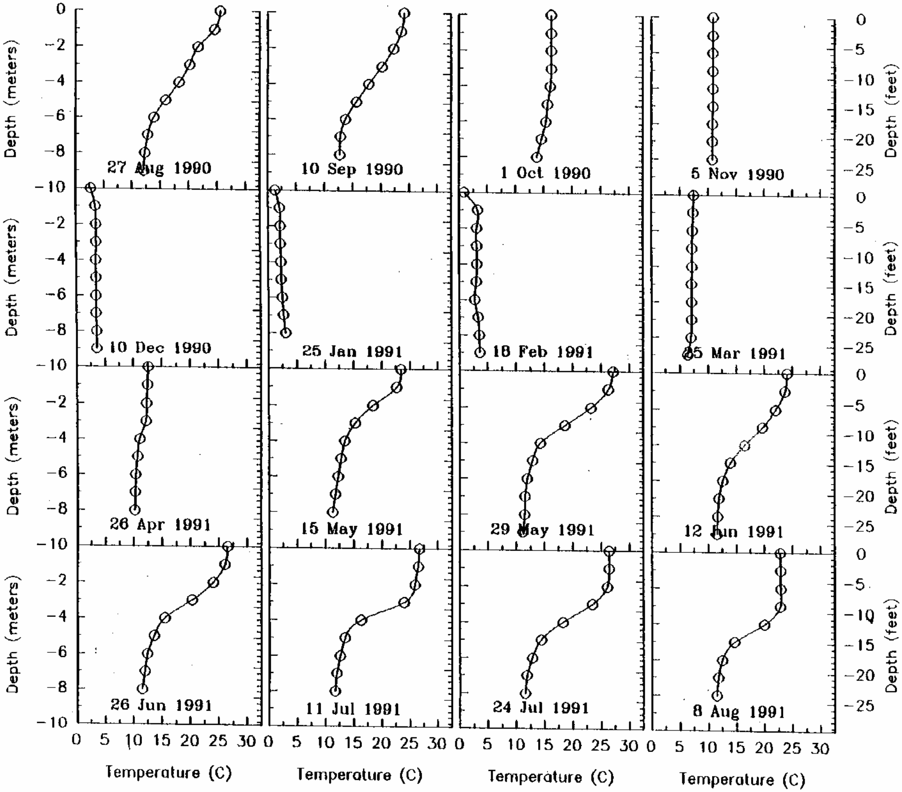
Alkalinity values are reported for both in-lake and Rimmell ditch stations (fig. 3; appendix III). Values range from 260 to 481 ppm in Rimmell ditch to 160 to 414 ppm in Skinner Lake. In general alkalinity values were higher in the tributary than in the lake on a given sampling date. Little difference was noted between samples taken from stations above and below the sedimentation trap as well as between the epilimnetic and hypolimnetic composite samples on given dates or pre- and post-construction.

The pH range of both in-lake (fig. 4, Appendix IV) and tributary (fig. 5, Appendix V) samples showed values around neutrality. No good correlation appears evident between alkalinity and pH changes in the lake water column.

Conductivity of lake and tributary waters is seen in Figures 6 and 7, respectively (Appendices VI and VII). Wetzel (8) noted a direct correlation between pH and conductance in fresh water but that the relationship is unstable in the presence of high organic matter. Values obtained in the tributary show a greater conductivity upon leaving the sedimentation trap than upon entering it. Increasing alkalinity does correspond with increasing conductivity in Rimmell ditch samples. No data comparable with that reported above is given in the previous study of Skinner Lake (6). Therefore no direct comparison can be made although some may be implied through other data presented. Comparative data will be presented in the results given for total phosphorus, total nitrogen, total suspended solids (reported as SPM in 1982 report) and, to a lesser degree, *chlorophyll a.*

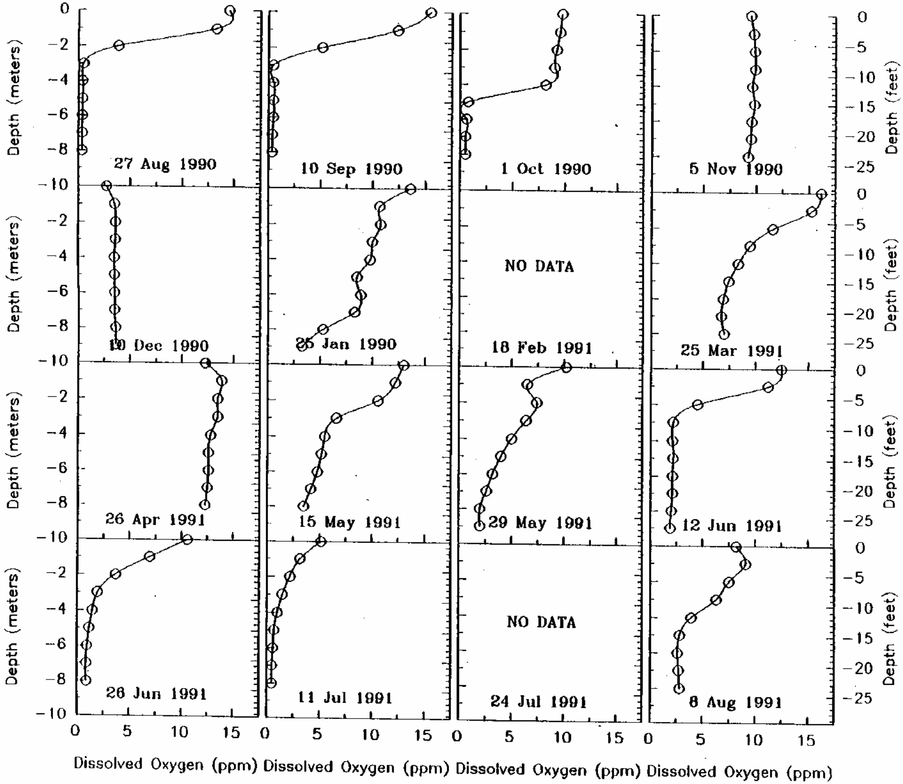
The limiting growth factor in most freshwater environments is phosphorus. For this reason, studies on freshwater ecosystems have focused on the availability of this element. The same is true for the Skinner Lake project. Results of total phosphorus obtained during the present study are presented in Figure 8 (Appendix VIII). Values are presented in mg/l. Rimmell values range from a low of 0.03 mg/l at the entrance to the lake, in February, to a high of 0.61 mg/l at the entrance to the sedimentation trap in November 1990. (High values in November for both Rimmell in and Rimmell out samples correspond with a heavy rain during sampling.) Late summer samples (after reconstruction of the wetland), showed a somewhat stable, general trend toward decreased TP(total phosphorus)

Figure 1. Temperature ($^{\circ}C$) profile of Skinner Lake, Noble County, IN, taken August 1990 through August 1991.



Depth (meters)
Depth (feet)
Temperature (C)
27 Aug 1990
10 Sep 1990
1 Oct 1990
5 Nov 1990
10 Dec 1990
25 Jan 1991
18 Feb 1991
25 Mar 1991
26 Apr 1991
15 May 1991
29 May 1991
12 Jun 1991
26 Jun 1991
11 Jul 1991
24 Jul 1991
8 Aug 1991
0 5 10 15 20 25 30
0 −2 −4 −6 −8 −10
0 −5 −10 −15 −20 −25

Figure 2. Dissolved oxygen (ppm) profile taken at Skinner Lake, Noble County, IN, August 1990 to August 1991.


Depth (meters)
Depth (feet)
Dissolved Oxygen (ppm)
27 Aug 1990
10 Sep 1990
1 Oct 1990
5 Nov 1990
10 Dec 1990
25 Jan 1990
18 Feb 1991
NO DATA
25 Mar 1991
26 Apr 1991
15 May 1991
29 May 1991
12 Jun 1991
26 Jun 1991
11 Jul 1991
24 Jul 1991
NO DATA
8 Aug 1991

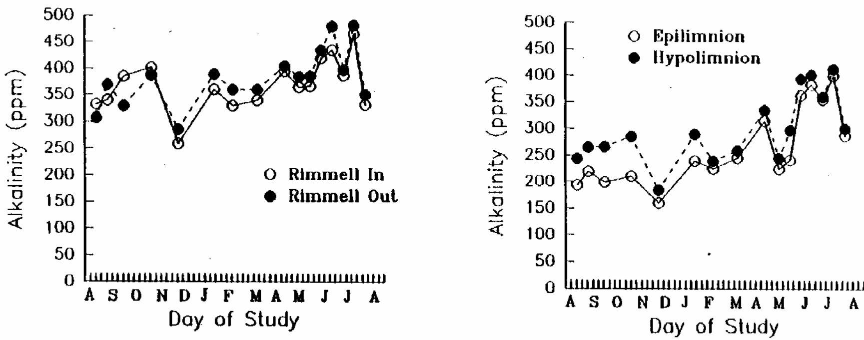
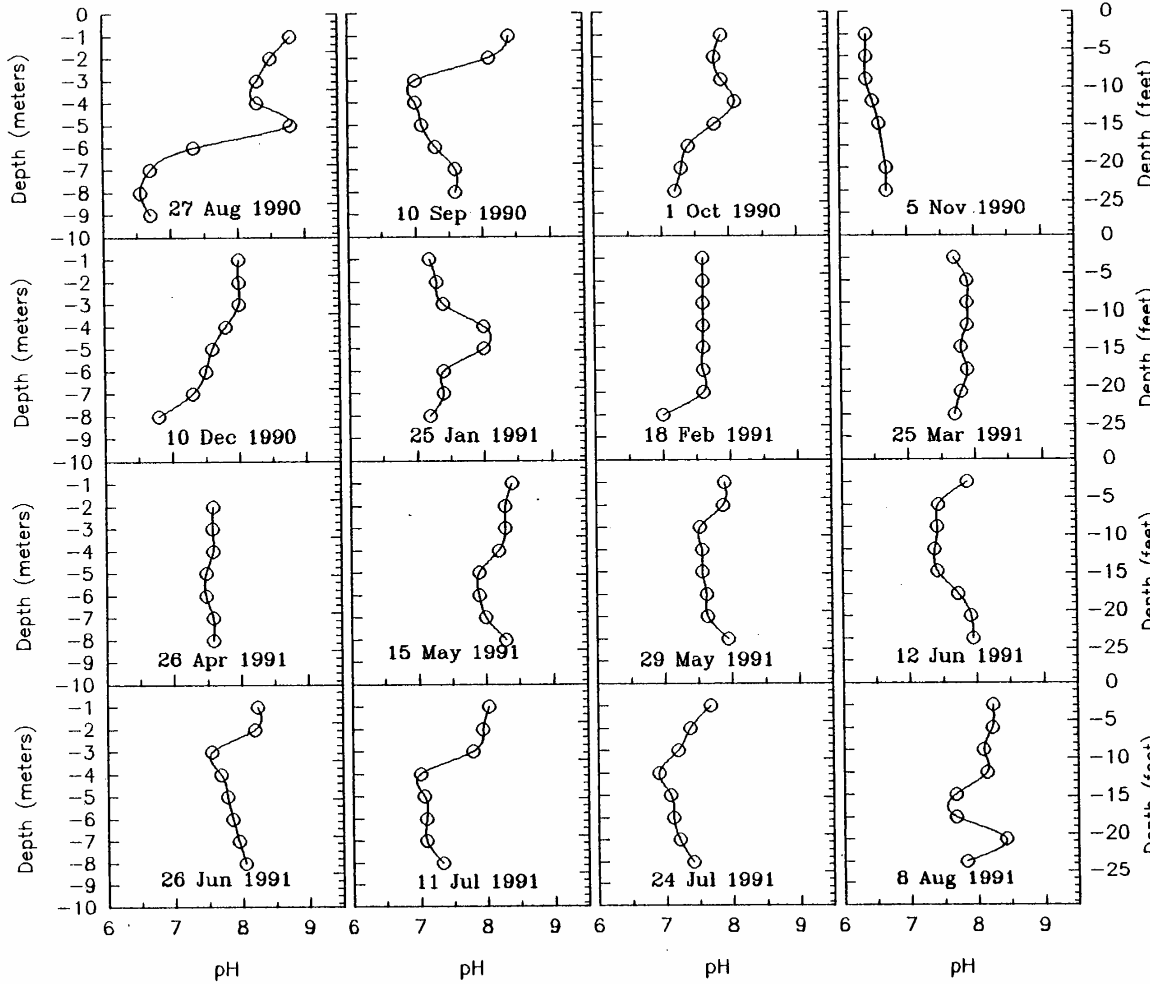


Figure 3. Alkalinity values (ppm) on Skinner Lake and Rimmell tributary, Noble County, IN, taken August 1990 through August 1991.

Figure 4. pH values obtained on Skinner Lake, Noble County, IN, taken August 1990 through August 1991.


27 Aug 1990
10 Sep 1990
1 Oct 1990
5 Nov 1990
10 Dec 1990
25 Jan 1991
18 Feb 1991
25 Mar 1991
26 Apr 1991
15 May 1991
29 May 1991
12 Jun 1991
26 Jun 1991
11 Jul 1991
24 Jul 1991
8 Aug 1991
Depth (meters)
Depth (feet)
pH

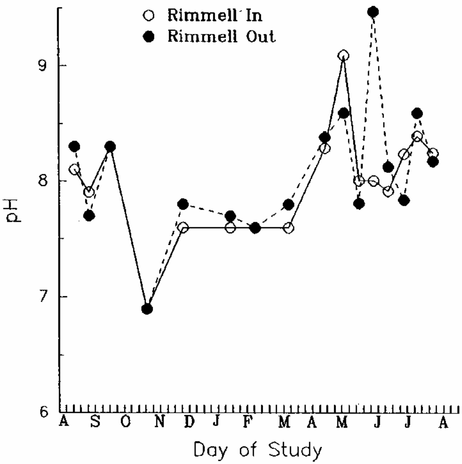
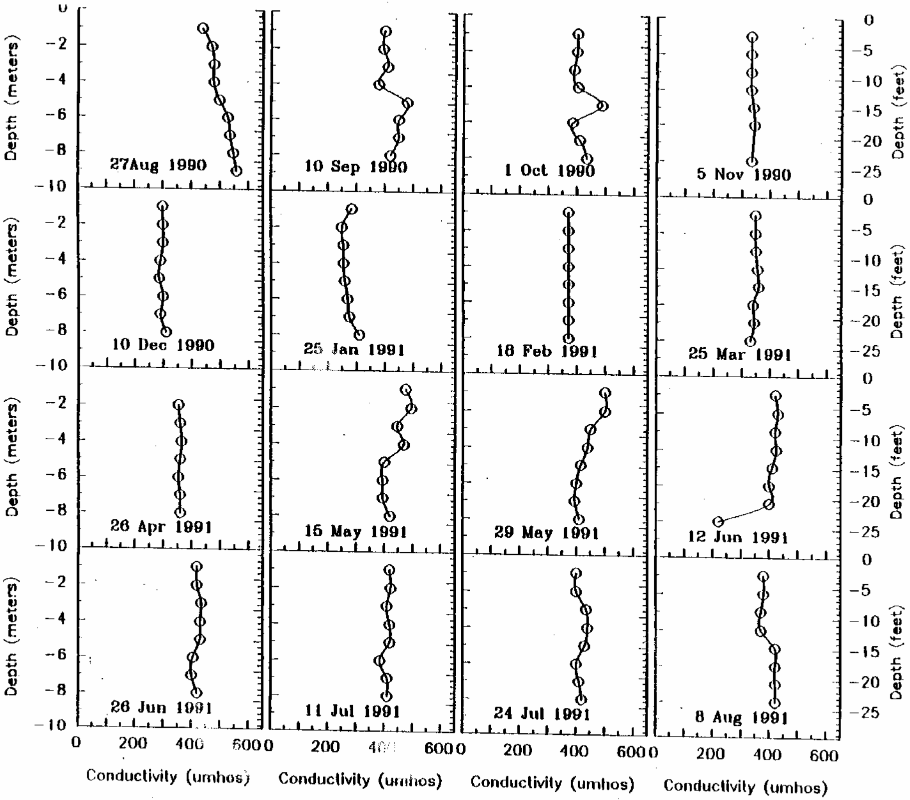


Figure 5. pH values of Rimmell tributary, Noble County, IN, taken August 1990 through August 1991.

Figure 6. Conductivity (umhos cm^{-1}) profile taken at Skinner Lake, Noble County, IN, August 1990 through August 1991.



27Aug 1990
10 Sep 1990
1 Oct 1990
5 Nov 1990
10 Dec 1990
25 Jan 1991
18 Feb 1991
25 Mar 1991
26 Apr 1991
15 May 1991
29 May 1991
12 Jun 1991
26 Jun 1991
11 Jul 1991
24 Jul 1991
8 Aug 1991
Depth (meters)
Depth (feet)
Conductivity (umhos)

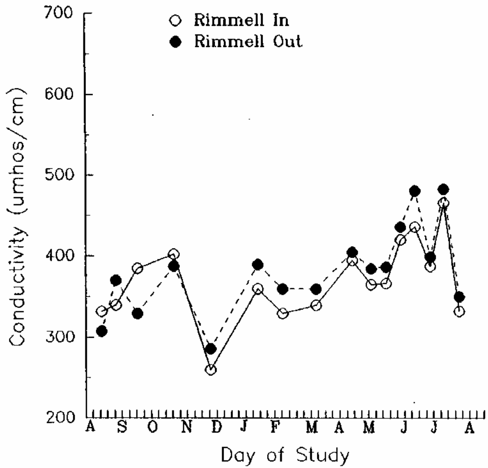


Figure 7. Conductivity (umhos/cm) taken from Rimmell tributary, Noble County, IN, August 1990 through August 1991.

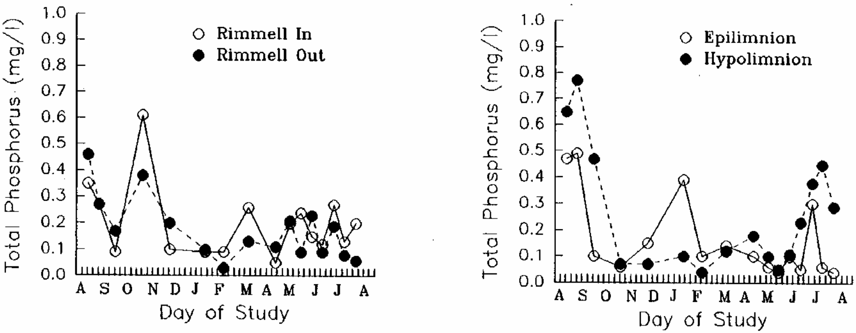


Figure 8. Total phosphorus (TP) reported in mg/l in Skinner Lake and Rimmell Tributary, Noble County, IN, August 1990 through August 1991.

leaving the basin as opposed to entering the basin. This was not evident in the late summer/early fall samples of 1990. The four 1991 sampling dates (6/26, 7/11, 7/24, 8/8) indicate a net mean difference of 0.3 mg/l (.72 mg/l - .42 mg/l) or a net decrease of nearly 42% in water leaving the basin. (This is based on comparison of concentrations without regard to flow.) McNabb(6) showed a late June decrease of 0.066(.161 mg/l - .095mg/l) or a net decrease of 41% comparable to the present study. The August/September 1990 samples showed a net input of TP from Rimmell In to Rimmell Out. In lake values ranged from a low in the epilimnion in August 1991 of 0.04 mg/l to a high of 0.77 mg/l in the hypolimnion in September 1990. Higher values were to be expected in the hypolimnetic waters. Similar or lower levels appeared in the lower portion of the water column during the winter months when no stratification was evident. The epilimnetic average of the present study was 0.15 mg/l compared to the previously reported value of 0.4 mg/l for Skinner Lake (5). Prior to construction of the wetland on Rimmell, epilimnetic TP (taken during an ice free period) ranged from 0.02 to 0.07 mg/l while hypolimnetic samples taken during the same period ranged from 0.5 to 2.3 mg/l in 1979(6).

Soluble (or ortho) phosphate is the form of phosphorus most readily assimilated by plants, animals and bacteria. In most natural waters the percentage of total phosphorus found as orthophosphate is usually considerably less than 5%(8). Sorption of orthophosphate on clay particles and metals is also quite common. Ortho (soluble) phosphorus values for lake composite samples and the Rimmell tributary sites are seen in Figure 9 (Appendix VIII). Above and below sedimentation basin values ranged from 0.1, on several occasions, to 0.38 mg/l in November 1990. Only in May 1991 did these values approach the 5% of the total phosphorus concentration suggested for natural waters (8). On three instances, more than 90% of total P was available as ortho phosphorus (October 1990, December 1990, and April 1991). Composite in-lake samples generally showed lower values than tributary data. During months exhibiting stratification, hypolimnetic values of both ortho and total phosphorus exceeded those of the epilimnetic composite samples. No pattern was discernible when thermal stratification was not present. Again, a relatively high percentage of total phosphorus was found as orthophosphate in lake composite samples as well.

The second element that will be compared between the McNabb study (6) and the present study is nitrogen. Nitrogen, although not usually a limiting nutrient in freshwaters, may become so in highly eutrophic conditions in which phosphorus is found in excess of biological need. Total nitrogen (TKN or TN) values (Figure 10, Appendix VIII) show extreme variability during the year. Tributary data show a low value of 0.53 mg/l on entrance to the lake in December 1990 with a high value of 53.9 mg/l on entrance to the sedimentation basin in March 1991. This high value may correlate with nitrogen fertilizer application by farmers. The spike observed in November 1990 is likewise probably related to surface runoff, in that sampling took place during a rain event. In lake TKN values ranged from a low in the epilimnion of 0.65 mg/l in November 1990 to a high of 59.08 mg/l in the epilimnion in May 1991. These summer values are a factor of 10 greater than those obtained in 1979 where ranges of whole lake samples were 1.28 to 5.61 mg/l and epilimnetic values ranged from 1.19 to 4.65 mg/l. Highest values of both studies occurred in May.

Ammonia is generated as a result of biological decomposition processes, or may enter water systems directly as a result of runoff after its application as a nitrogen fertilizer. Figure 11 (Appendix VIII) shows NH_3 levels obtained during the present study. Ammonia levels on the Rimmell ditch sites ranged from

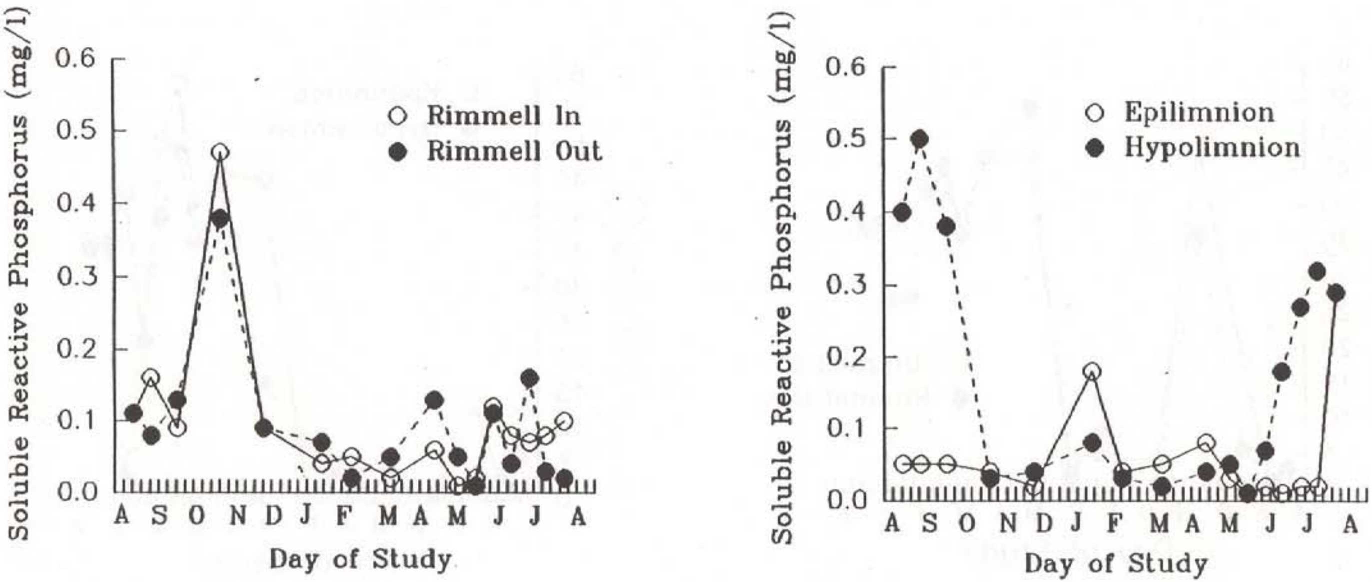


Figure 9. Ortho phosphorus reported in mg/l in Skinner Lake and Rimmell tributary, Noble County, IN, August 1990 through August 1991.

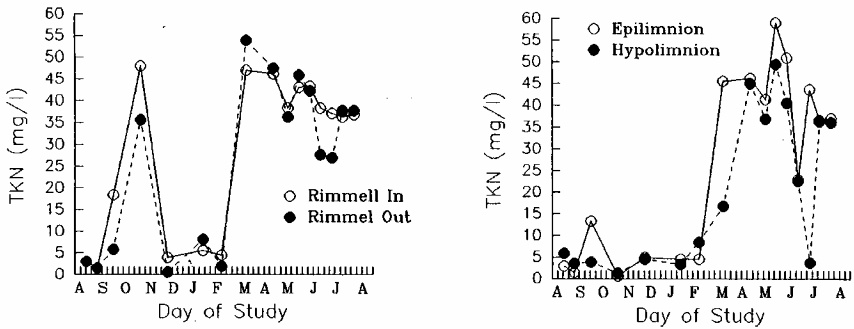


Figure 10. Total Kjeldahl nitrogen (TKN) reported in mg/l in Skinner Lake and Rimmell tributary, Noble County, IN, August 1990 through August 1991.

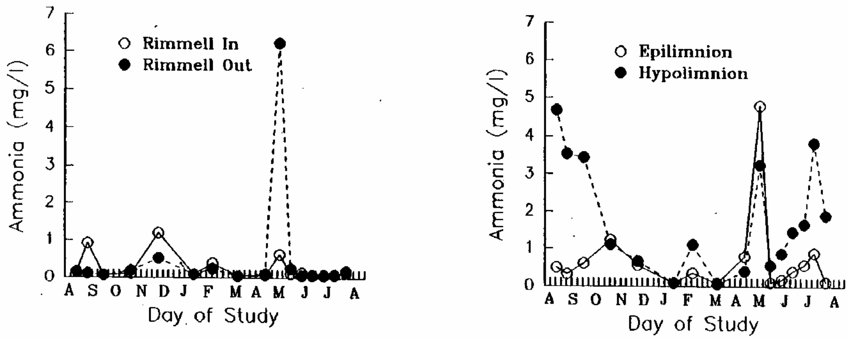


Figure 11. Ammonia reported in mg/l in Skinner Lake and Rimmell tributary, Noble County, IN, August 1990 through 1991.

0.04 mg/l in March 1991 to 6.25 mg/l in May 1991. Levels are relatively low indicating its high incorporation rate that may nearly match its release as the result of decomposition. The high May spike found in both the tributary and the lake is a likely indication of its application on nearby fields. In lake ammonia levels range from 0.05 mg/l in the hypolimnion composite in March to a high of 4.8 mg/l in the epilimnion in May. General increasing NH_3 was observed in the hypolimnetic samples during summer stratification when O_2 was low or depleted. Here, ammonia values are likely the result of anaerobic decomposition. Little difference was noted when ice cover existed or when the lake showed no thermal stratification. The epilimnetic peak in May 1991 is likely the result of fertilizer application and/or significant rainfall.

Nitrate and nitrite may result from biological oxidative activity or, in the case of nitrate, be found in water as a result of nitrogen fertilizer application. Both should be found in relatively low amounts since they are highly reactive and easily immobilized. Figures 12 and 13 (Appendix VIII) give the nitrate and nitrite concentrations, respectively in both Rimmell and lake samples. A noticeable feature of both figures was a peak in early June in both the Rimmell tributary and in-lake samples. Its appearance may be correlated with nitrate based fertilizer applications. During lake thermal stratification, levels of nitrate and nitrite should be lower in the hypolimnion due to the reducing environment present. This, however, was not readily evident.

Total and suspended solids were analyzed in both this and the 1982 report on Skinner Lake (6). Solids retained in water may adversely effect water quality, water taste and, therefore, water use (1). Total dissolved solids(TDS) are those which are filterable while suspended solids are particulate and will not pass through filters. Total suspended solids(TSS) will be used synonymously with suspended particulate matter (SPM) as discussed in the 1982 report (6). Total suspended solids were relatively low in lake and Rimmell ditch samples(Figure 14; Appendix VIII). With the exception of the November sample all samples were below 100 mg/l with most below 50 mg/l. Excluding the November sample, the mean Rimmell in(RI) TSS was 30.9 mg/l while the Rimmell out(RO) was 22.4 mg/l. (Because sampling on this date occurred during a rain event, these values are not comparable to other data.) Including the November sample RI and RO were 50.6 and 31.2 mg/l respectively. During the April through June 1982 period, RI and RO were 26.1 and 23.2 mg/l, respectively (6). Comparing the same period of April through June for 1991 values of 30.8 and 21.6 mg/l for RI and RO were obtained respectively. These values occurred after construction of the wetland on Rimmell basin. Total dissolved solids (Figure 15; Appendix VIII) showed little pattern with regard to seasons or sampling sites. Values ranged from 251 mg/l to 614 mg/l.

Secchi disk transparency is a simple way of determining water clarity (8). It can also be used for productivity analysis, lake trophic indices and algal biomass estimates. It is presently being promoted by the Indiana Department of Environmental Management as a way to help cottage owners on Indiana lakes monitor water quality. Water clarity was not high in Skinner Lake (Figure 16). Most sampling dates showed a value of 0.9m or approximately 2.5 feet.

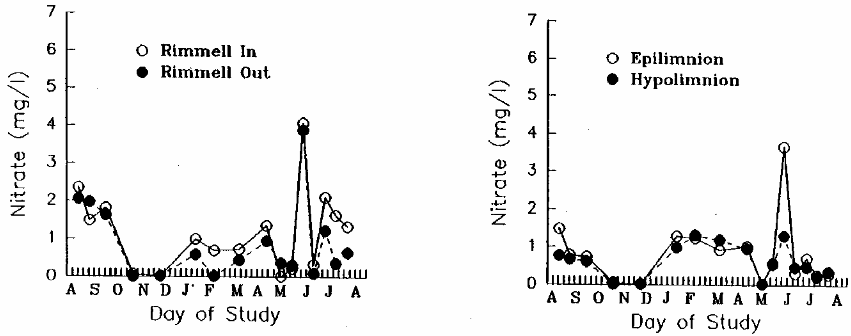


Figure 12. Nitrate reported in mg/l in Skinner Lake and Rimmell tributary, Noble County, IN, August 1990 through 1991.

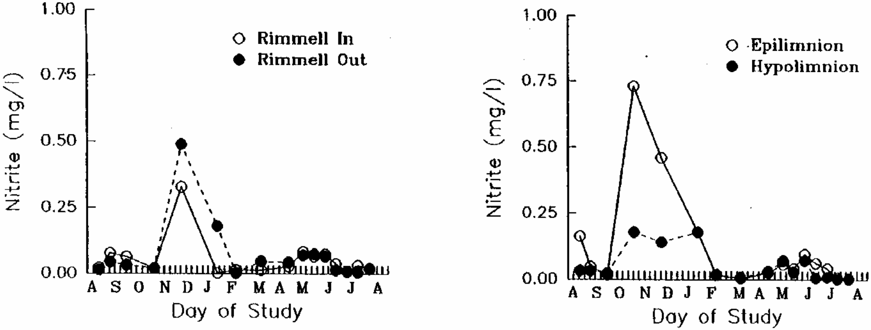


Figure 13. Nitrite reported in mg/l in Skinner Lake and Rimmell tributary, Noble County, IN, August 1990 through August 1991.

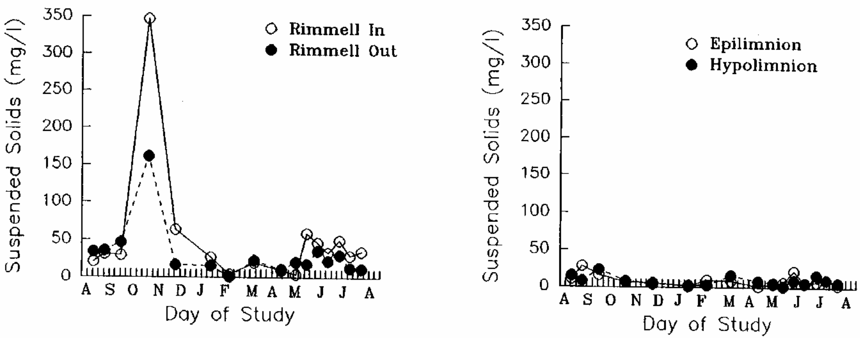


Figure 14. Total suspended solids (TSS) reported in mg/l in Skinner Lake and Rimmell tributary, Noble County, IN, August 1990 through August 1991.

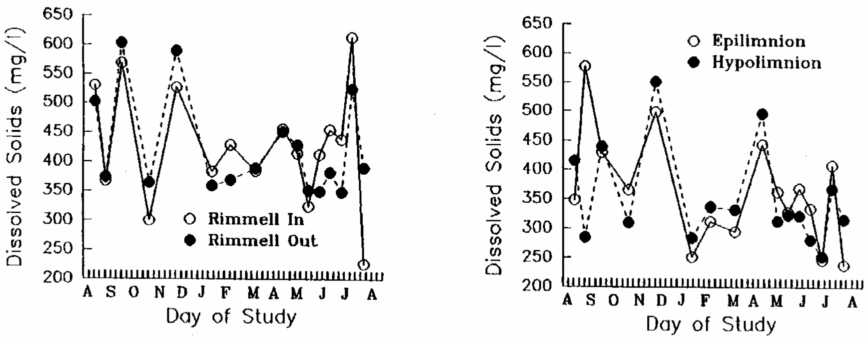


Figure 15. Total dissolved solids (TDS) reported in mg/l in Skinner Lake and Rimmell tributary, Noble County, IN, August 1990 through August 1991.

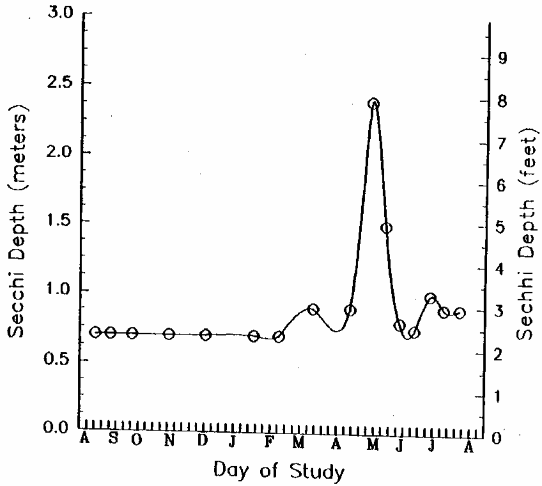


Figure 16. Secchi disc transparency for Skinner Lake, Noble County, IN, August 1990 through August 1991.

Another parameter often correlated with Secchi disk transparency readings is *chlorophyll a* concentration. *Chlorophyll a* is the major light-trapping pigment in photosynthetic organisms. Its concentration in water is directly related to the photosynthetic capabilities and algal biomass present in an aquatic water system (1). Figure 17 (Appendix VIII) shows chlorophyl a values obtained over the year long study. Simultaneous data collected on algal biomass, volume and diversity have raised concern over these results. Low *chlorophyll a* values in January and March in particular. Another apparent result of our sampling indicates little variability within the water column on a given day. Values ranged up to 0.266 mg/l in an early September sample. Those values obtained by McNabb (6) prior to construction of the first sediment trap yielded between approximately 0.014 mg/l to 0.027 mg/l; an approximate ten-fold decrease when compared to the 1990-1 data.

An analysis of the algal populations show that an extremely high proportion of cyanobacteria were present in all instances. The community was dominated by Microcystis aeruginosa and Oscillatoria sp. with some Asterionella formosa and other algal species occurring in low numbers. Cell numbers surpassed 10^4 per ml when bloom conditions were noted during June and July (fig. 18). Algal biomass (fig. 19) shows peak values approaching 10^9 ug ml^{-1} in the warmer summer months. Biomass below the thermocline may be representative of dead and dying populations.

The zooplankton community of the lake was typical in respect to its composition of cladocerans, copepods, and rotifers. Cladocera were represented by Daphnia hyalina, D. retrocurva, Bosmina longirostris, Diaphanosoma birgei and Leptodora kindtii. D. hyalina was most numerous (> $2X10^5 m^{-2}$) and present throughout the study period. D. retrocurva was less numerous, showing highest abundance on November 5. B. longirostris was far less numerous than the Daphnia species, being most abundant from May to July. D. birgei appeared only in July and August. Leptodora kindtii was represented by a few individuals on April 26 and May 29.

Among the copepods, Diacyclops thomasi was the dominant cyclopoid copepod during the winter months of the study. The males, females and copepodids all increased from November 5 to April 26, when the population was the highest (>$9X10^5 m^{-2}$). The copepodids were more numerous than the adults during the entire study. From May 15 to July 24, no adults were seen at all.

Mesocyclops edax was the dominant, summer cyclopoid copepod. It was not observed until June 12. The adults were dominant over the copepodids and both the males and females peaked on July 24(>$6X10^1 m^{-1}$). Tropocyclops prasinus, another cyclopoid copepod, also appeared during the last two months of the study, but in very low numbers. Orthocyclops modestus was observed in March, February and May.

Cyclopoid nauplii and calanoid nauplii numbers were almost equal, approaching (1.0 X $10^5 m^{-2}$) during the entire study. The cyclopoid nauplii populations however, were slightly larger from February 15 to July 10 and peaked greatly on May 15. On the other hand the calanoid nauplii numbers never peaked and outnumbered the cyclopoid nauplii only on November 5, December 10, July 10 and 24, and August 8.

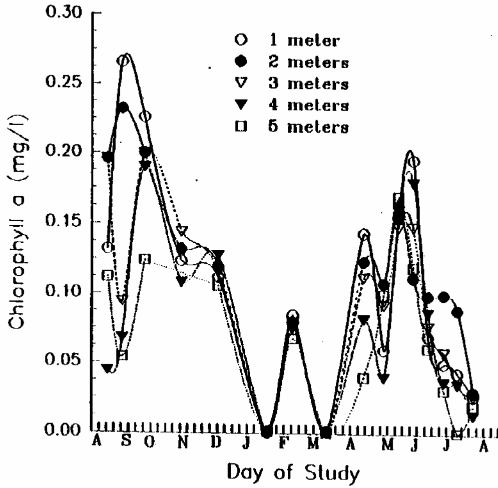
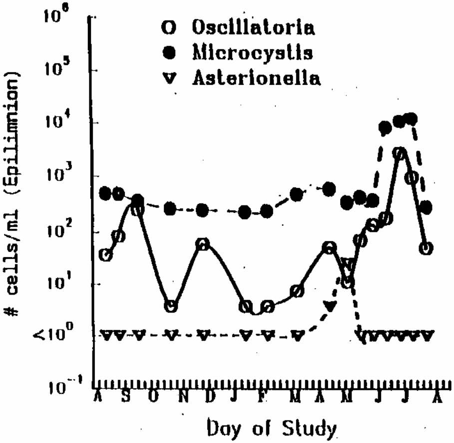


Figure 17. *Chlorophyll a* (mg/l) in the water profile of Skinner Lake, Noble County, IN, August 1990 through August 1991.



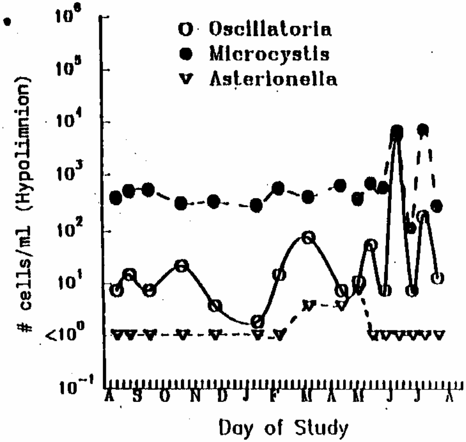


Figure 18. Algal cell numbers (cells ml^{-1}) in epilimnetic and hypolimnetic composite water samples from Skinner Lake, Noble County, IN, August 1990 through August 1991.

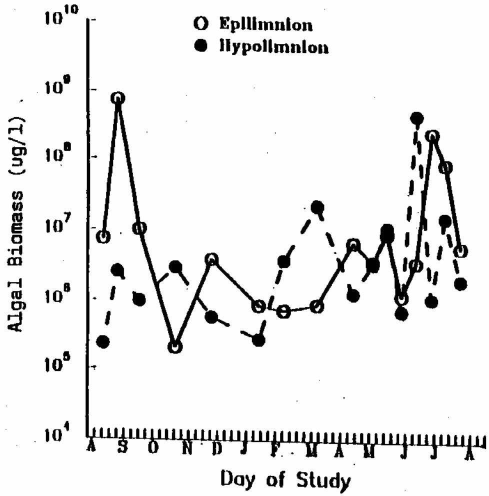


Figure 19. Combined algal biomass (ug/l) in epilimnetic and hypolimnetic composite samples from Skinner Lake, Noble County, IN, August 1990 through August 1991.

Skistodiaptomus oregonensis was the dominant calanoid copepod from November 5 through May 15 approaching 1.4 X 10^4 cell m^{-2}. The females outnumbered the males and showed very high populations on January 25, March 15 and May 15, but were absent from June to the end of the study.

Onychodiaptomus birgei was very abundant from May 29 to June 12 approaching 3 X 10^4 m^{-2}, but was also well represented from December 10 to May 15. The males were, on the average, more abundant than the females.

Rotifers were observed all during the entire study but in low numbers. Asplanthna priodonta, Kellicottia bostoniensis, Keratella cochlearis and Keratella quadrata were all noted but were never present in any great abundance. However, K. cochlearis did become more abundant May 15 to August 8.

Total plate counts of heterotrophic bacteria were 10^4 cell ml^{-1} in the thermocline with somewhat lower values into surface waters. The chitinolytic population represents approximately 10% of the identifiable heterotrophic population at the surface and thermocline. The bacterial populations are the primary decomposers in aquatic systems. Their activity is highest at interface such as those sampled: the air/water and thermocline. Chitin decomposition was examined because it is a major biomolecule found in aquatic systems. It is part of the exoskeleton of emerging insects, provides the structural integrity to fungi and is a major constituent of both micro- and macrocrustaceans.

No positive identification of herbicides or pesticides was made in Rimmell ditch water taken June 12, 1991. Although pesticides such as atrazine may be detected in water several weeks after its application(7), none were detected. Studies continue to assess the impact atrazine may have on the morphology, physiology and metabolism of a selected bacterial isolate from Skinner Lake.

Macrophyte analysis of the vegetation surrounding and within Skinner Lake may be seen in Figure 20. The lake supports a low diversity community dominated by arrow arum (Peltandra viriginica L.), spatterdock (Nuphar advena Ait) and waterlillies (Nymphaea odorata Ait). In the northwestern and southeastern corners of the lake these species along with pickerelweed (Pontderia cordata L.) form distinct zonal patterns. From open water to buttonbush shrub thicket the sequence is waterlillies-spatterdock-arrow arum and pickerelweed-buttonbush.

The waterlillies are found as descrete patches growing around the shoreline of the lake. They are particularly prominent in the Northwestern and Southwestern corners. Elsewhere they occur as small colonial communities that survive the biannual spraying of herbicides by virtue of their large rhizomes. Spatterdock and arrow arum are much more prolific. They tend to "take over" an area, given a chance, forming extensive mixed culture mats. These are controlled in the cottage areas by the use of herbicides to keep the docks free of aquatic macrophytes. In areas without cottages the spatterdock-arrow arum-pickerelweed association quickly forms an extensive mat.

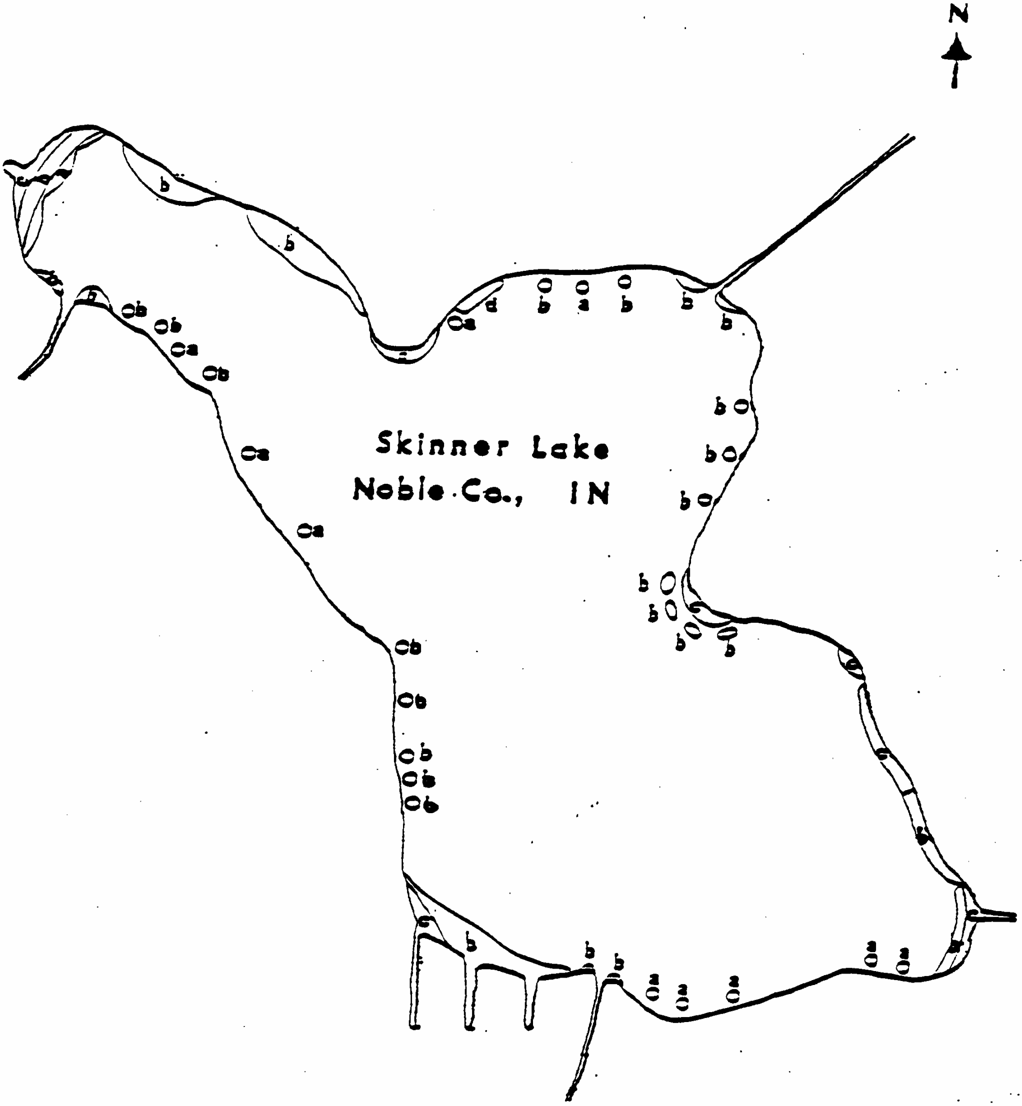


Figure 20. Macrophyte analysis of shoreline of Skinner Lake, Noble County, IN, during the summer of 1991. Three zones identified as *Nymphaea* (a); *Nuphar-Peltandra-Pontederia* (b); and *Cephalanthus-Salix* shrub (c).

Several species occur occasionally in the spatterdock-arrow arum mats. The most frequent is pickerelweed. Next is water pepper (Polygonum hydropiperoides Michx), lizards tail (Saururus cernuus L.), purple loosestrife (Lythrum salicaria L.), swamp loosestrife (Decodon verticillatus(L Ell.), reed canary crass (Phalaris arundinacea L.), catails (Typha angustifolia L. and Typha latifolia L.), and rushes (Scirpus americanus Pers and Scirpus validus Vahl).

Calculation of trophic state indices provides an indication of lake "health" or "age". Both the ISBH and Carlson indices have been determined. The ISBH value of Bonhomme is outlined in the IDEM publication(5) which has placed Skinner Lake as Class III with ISBH index of 45. Present data show ISBH index of 60 (Appendix XI) which would put this lake in Class III based on trophic status, those lakes indicating lowest water quality.

Carlson(2) TSI may be calculated using *chlorophyl a* concentration, secchi disk transparency, and/or total phosphorus using the following equations:

$$TSI(chl) = 10\ 6 - \frac{2.04-0.68 \ln chl}{\ln 2}$$

$$TSI(SD) = 10\ 6 - \frac{\ln SD}{\ln 2}$$

$$TSI(TP) = 10\ 6 - \frac{\ln \frac{48}{TP}}{\ln 2}$$

We used *chlorophyl a* values taken at 1 meter averaged over the year excluding the months of January and March(120 mg/m^3). Epilimnetic TP was used during summer stratification (May - August)(106 mg/m^3). Secchi disk transparency used was the average value over the summer(0.9m). TSI values of 77.7, 61.6, and 71.2 were determined for Skinner Lake for *chlorophyll a*, secchi disk, and total phosphorus, respectively. These values place the lake in a highly eutrophic state.

Discussion

Several unexpected results have come out of the present study. The extremely high levels of phosphorus and nitrogen raise concern. As major factors determining the productivity of waters they may be the significant findings. It is too early to make any conclusions on the impact the sedimentation basin may have on these nutrients. It is noted, however, that phosphorus levels had a marked decline following reconstruction of the basin. The sorptive qualities of phosphorus species on clay and other particulates are the likely cause of this reduction(3). Nitrogen species on the other hand, do not generally display this quality. Their increase after the reconstruction of the basin shows the effects of perturbation on the ecology of the area. The impact of rain on the nutrient inflow to the lake can be readily identified from the November sampling. Along with the particulate matter transported into the lake, the rain brings run-off from fields fertilized for maximum harvest yield. Other nonpoint sources, not examined in the study, such as lawn fertilizers, septic systems and the like will also have impact on lake water quality and productivity.

The high productivity of the lake was evidenced by algal blooms. The predominant algal species were blue greens which require the highest phosphorus content for their growth. The bluegreens, or cyanobacteria, are major light harvesters and their populations account for most of the biomass of the lake. In so doing, they create aesthetic problems (green tainted water) as well as odor and potential toxic problems (1). Their presence forms the base for a highly productive food chain. The zooplankton communities multiply effectively on this base and provide further evidence for a productive fish population, in terms of biomass if not diversity. Studies of the fish population would be required to verify this premise.

On several occasions over the course of this study, algal populations remained high while *chlorophyll a* levels declined or were nearly non-existent. Some of this seeming discrepancy may be ascribed to incorporation of dead or dying algal populations in cell counts. Hypolimnetic samples even during times of thermal stratification showed significant algal counts although light penetration or cycling to a light regime is extremely doubtful. Therefore, the low *chlorophyll a* and relatively high algal counts may thus be explained. During algal blooms of the late summer, the populations multiply to high levels and then crash as the result of cell age, nutrient depletion, turbidity, toxicity and other physical and biological factors.

Eutrophication in Skinner Lake will continue if nutrient levels entering and within the lake remain high. The reconstructed sediment trap may be doing a very similar job to what it did when first constructed in the early 1980's. No follow up was conducted in the intervening years, however, to verify the effectiveness of the project. The decrease in phosphorus loading indicates that similar results may be expected today as was found in 1982. This, however, may slow the eutrophoication process but surely not reverse it. The present data on both biological and chemical sides would indicate that the lake might be classified as hypereutrophic (8). Both the Bonhomme index and Carlson's would also support such a conclusion. Nothing found in the present study would indicate that the recent activity would have a significant positive impact. Even a 40% decline in phosphorus, although valuable, would not be enough to lower this limiting nutrient to a level that would change lake trophic index to mesotrophic range.

The macrophyte growth can be problematic and often considered a detriment to water use from a recreational point of view. For this reason, herbicides are routinely used to minimize their growth. This has a major impact on the distribution and abundance of emergent aquatic macrophytes in the lake. Littoral drift of the herbicide accounts for its effects beyond the zones of immediate spraying. The repeated spraying has had the additional effects of reducing the diversity of species that emerge following the spraying events. Those species with large rhizomes are more quick to recover. The herbicide is effective in controlling the emergence of aquatic plants in the dock areas. Additionally, the herbicide is responsible for the low diversity and lack of extensive areas of macrophytes in Skinner Lake. In the absence of the plant control measures, currently being taken, it be would expected that the lake would be ringed with an aquatic vegetation zone out to 15-20 or more feet from the shoreline.

All factors examined, therefore, indicate a highly productive lake that will continue to be so. Further studies to determine the impact of the sedimentation basin would have to be conducted at a later time to verify this assumption. Water quality during the present study has shown itself to have decreased from that reported by the Michigan State study of the lake (6) and that reported in the Indiana lake classification project (5).

Conclusions

1. Water chemistry and algal biomass data indicate a highly eutrophic lake.

2. Both Carlson's and ISBH trophic indices indicate a lake with high phosphorus intake; possibly approaching a state where nitrogen may be limiting.

3. Comparison between 1979 and the present shows little improvement. The lake process of aging, however, may have been slowed by the sedimentation basin.

4. It is too early to deduce the impact of the reconstructed sediment basin. Most recent data, although inconclusive, seem to lead one to believe that total phosphorous from Rimmell ditch may be decreased by as much as 40%.

5. Nitrogen inputs, as affected by the reconstructed basin appear to have increased over earlier values of the 90-91 year, and over data of 1978-81.

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Appendix I

Temperature (^{o}C) profile of Skinner Lake, Noble County, IN, taken August 1990 through August 1991

	DEPTH	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY 15	MAY 29	JUN 12	JUN 26	JUL 11	JUL 24	AUG 8
1	0	25.6	24.2	16.4	10.9	2.7	1.3	0.8	7.5	12.6	23.5	27.2	24.1	26.5	26.7	26.4	22.8
2	-1	24.6	23.7	16.4	10.9	3.5	2.1	3.3	7.4	12.5	22.7	26.3	23.7	26.1	26.5	26.4	22.9
3	-2	21.65	22.3	16.4	10.9	3.6	2.2	3.1	7.3	12.3	18.5	23.2	22	24	25.9	26.1	22.9
4	-3	20.15	20.25	16.4	10.9	3.6	2.2	3.1	7.2	12.2	15.3	18.6	19.7	20.3	24	23.4	22.8
5	-4	18.35	17.9	16.2	10.9	3.5	2.3	3.1	7.2	11.1	13.5	14.3	16.5	15.5	16.3	18.2	20
6	-5	15.95	15.7	15.7	10.9	3.5	2.3	3	7.1	10.7	12.8	12.9	14	13.6	13.5	14.4	14.7
7	-6	13.85	13.75	15.4	10.8	3.5	2.5	2.7	7.1	10.4	12.3	12	12.6	12.4	12.6	12.8	12.5
8	-7	12.85	12.85	14.6	10.8	3.5	2.7	3.3	7.1	10.3	11.8	11.6	11.9	12	12	11.9	11.8
9	-8	12.3	12.75	13.8	10.8	3.6	3	3.5	7	10.2	11.3	11.5	11.7	11.5	11.7	11.6	11.5
10	-9	12.1				3.6		3.6	6.4			11.2	11.6				

Appendix II

Dissolved oxygen (ppm) profile taken at Skinner Lake, Noble County, IN, August 1990 through August 1991

		AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY 15	MAY 29	JUN 12	JUN 26	JUL 11	JUL 24	AUG 8
1	0	14.5	15.5	9.7	9.46	2.7	13.6		16.2	12.3	13	10.2	12.5	10.6	5.2		8.2
2	-1	13.3	12.4	9.5	9.72	3.5	10.7		15.3	13.9	12.2	6.5	11.2	7	3.2		9.1
3	-2	3.9	5.2	9.2	9.86	3.6	10.8		11.6	13.5	10.6	7.4	4.5	3.7	2.2		7.5
4	-3	0.5	0.5	9	9.9	3.6	10		9.4	13.5	6.6	6.4	2.2	2	1.5		6.3
5	-4	0.4	0.5	8.1	9.6	3.5	9.8		8.3	12.8	5.5	5	2.1	1.5	1		3.9
6	-5	0.4	0.5	0.8	9.81	3.5	8.5		7.4	12.6	5.2	4	2.2	1.2	0.7		2.8
7	-6	0.4	0.5	0.6	9.53	3.5	8.9		6.9	12.6	4.8	3.2	2.1	1	0.6		2.6
8	-7	0.4	0.4	0.5	9.45	3.5	8.3		6.7	12.5	4.2	2.6	2.1	0.9	0.5		2.7
9	-8	0.4	0.4	0.5	9.21	3.6	5.3		7	12.3	3.5	2	2	0.9	0.5		2.8
10	-9					3.6	3.3					2	1.9				

Appendix III

Alkalinity values (ppm) on Skinner Lake and Rimmell tributary, Noble County, IN, taken August 1990 through August 1991

				RIM IN	RIM OU	EPILIM	HYPOLIM
1	1	1	AUG 27	332	308	194	244
2	15	2	SEP 10	340	370	220	266
3	36	3	OCT 1	385	330	199	267
4	71	4	NOV 5	402	388	210	286
5	106	5	DEC 10	260	286	160	185
6	152	6	JAN 25	360	390	240	290
7	176	7	FEB 18	330	360	225	240
8	208	8	MAR 25	340	360	245	260
9	243	9	APR 26	395	405	315	335
10	262	10	MAY 15	365	385	225	245
11	276	11	MAY 29	367	387	242	298
12	290	12	JUN 12	420	436	363	395
13	304	13	JUN 26	436	481	383	402
14	319	14	JUL 11	388	399	355	361
15	332	15	JUL 24	466	483	400	414
16	347	16	AUG 8	333	351	288	302

Appendix IV

pH values obtained on Skinner Lake, Noble County, IN, taken August 1990 through August 1991

	DEPTH	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY 15	MAY 29	JUN 12	JUN 26	JUL 11	JUL 24	AUG 8
1	0																
2	-1	8.8	8.4	7.9	6.4	8	7.2	7.6	7.7		8.4	7.9	7.87	8.24	8.03	7.67	8.23
3	-2	8.5	8.1	7.8	6.4	8	7.3	7.6	7.9	7.59	8.3	7.88	7.44	8.19	7.94	7.36	8.22
4	-3	8.3	7	7.9	6.4	8	7.4	7.6	7.9	7.58	8.3	7.53	7.42	7.55	7.19	7.18	8.09
5	-4	8.3	7	8.1	6.5	7.8	8	7.6	7.9	7.59	8.2	7.56	7.38	7.69	7	6.89	8.11
6	-5	8.8	7.1	7.8	6.6	7.6	8	7.6	7.8	7.48	7.9	7.56	7.42	7.78	7.06	7.07	7.67
7	-6	7.35	7.3	7.4		7.5	7.4	7.6	7.9	7.48	7.9	7.62	7.73	7.86	7.09	7.11	7.67
8	-7	6.7	7.6	7.3	6.7	7.3	7.4	7.6	7.8	7.59	8	7.64	7.92	7.95	7.09	7.2	8.42
9	-8	6.55	7.6	7.2	6.7	6.8	7.2	7	7.7	7.59	8.3	7.94	7.95	8.05	7.33	7.4	7.83
10	-9	6.7															

Appendix V

pH values of Rimmell tributary, Noble County, IN, taken August 1990 through August 1991

Sample #	Day #	Date	Rim. In	Rim. Out
1	1	Aug 27	8.1	8.3
2	15	Sep 10	7.9	7.7
3	36	Oct 1	8.3	8.3
4	71	Nov 5	6.9	6.9
5	106	Dec 10	7.6	7.8
6	152	Jan 25	7.6	7.7
7	176	Feb 18	7.6	7.6
8	208	Mar 25	7.6	7.8
9	243	Apr 26	8.29	8.39
10	262	May 15	9.1	8.6
11	276	May 29	8.01	7.81
12	290	Jun 12	8.01	9.48
13	304	Jun 26	7.92	8.13
14	319	Jul 11	8.24	7.84
15	332	Jul 24	8.4	8.6
16	347	Aug 8	8.25	8.18

Appendix VI

Conductivity (umhos/cm^{-1}) profile taken at Skinner Lake, Noble County, IN, August 1990 through August 1991

		AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY 15	MAY 29	JUN 12	JUN 26	JUL 11	JUL 24	AUG 8
1	0																
2	-1	436.5	400	402	332	300	285	370	349		475	500	420	420	420	400	380
3	-2	470.5	395	400	332	300	250	370	349	355	495	500	430	420	425	400	380
4	-3	477.5	410	390	332	300	255	370	350	360	445	450	420	435	410	435	370
5	-4	477.5	380	405	332	290	255	370	355	365	470	440	425	430	420	440	370
6	-5	497	480	488	340	285	260	370	360	360	400	415	410	430	420	430	420
7	-6	527.5	450	385	345	300	270	370	340	355	395	400	400	405	385	400	420
8	-7	535	450	410		290	275	370	345	360	395	395	400	400	410	410	420
9	-8	547	420	435	335	310	310	370	330	360	420	410	220	420	410	420	420
10	-9	558															
11																	
12																	
13																	
14																	
15																	
16																	

Appendix VII

Conductivity (umhos/cm^{-1}) profile taken from Rimmell tributary, Noble County, IN, August 1990 through August 1991

			RIM IN	RIM OU
1	1	AUG 27	332	308
15	2	SEP 10	340	370
36	3	OCT 1	385	330
71	4	NOV 5	402	388
106	5	DEC 10	260	286
152	6	JAN 25	360	390
176	7	FEB 18	330	360
208	8	MAR 25	340	360
243	9	APR 26	395	405
262	10	MAY 15	365	385
276	11	MAY 29	367	387
290	12	JUN 12	420	436
304	13	JUN 26	436	481
319	14	JUL 11	388	399
332	15	JUL 24	466	483
347	16	AUG 8	333	351

Appendix VIII. Chemical values (mg/l) on Skinner Lake composite samples and Rimmell tributary, Noble County, IN, taken August 1990 through 1991. Rimmell In (RIM IN) data are those taken prior to the sediment basin while Rimmell Out (RIM OUT) data are those taken in water leaving the sedimentation basin and entering the lake. Epilimnetic (EPILIM) data are those of composite samples taken at depths of 1,2,3, and 4 meters, while hypolimnetic (HYPOLIM) data are those of composite samples taken at depths of 5,6,7, and 8 meters. Chlorophyl a (CHL. A) data are shown at 1 meter intervals where 1 meter represents sample taken at 1 meter depth from surface waters. See text for other abbreviations.

SKINNER LAKE SPREAD SHEET

DATE	8/27/90	9/10/90	10/1/90	11/5/90	12/10/90	1/28/91	2/18/91	3/25/91	4/16/91	5/13/91	5/29/91	6/12/91	6/26/91	7/11/91	7/24/91	8/8/91	AVERAGE
TOTAL PHOS																	
RUNNEL IN	0.19	0.27	0.09	0.61	0.3	0.49	0.09	0.36	0.05	0.2	0.24	0.15	0.12	0.27	0.13	0.3	0.20133
RUNNEL OUT	0.18	0.27	0.37	0.30	0.3	0.1	0.03	0.13	0.21	0.31	0.09	0.23	0.09	0.13	0.08	0.08	0.175
EPILIMNION	0.17	0.49	0.1	0.06	0.15	0.30	0.1	0.14	0.1	0.09	0.06	0.1	0.03	0.03	0.08	0.08	0.14875
HYPOLIMNION	0.48	0.77	0.37	0.07	0.07	0.1	0.04	0.12	0.10	0.1	0.05	0.11	0.23	0.39	0.15	0.28	0.255
ORTHO PHOS																	
RUN IN	0.12	0.16	0.09	0.47	0.09	0.04	0.05	0.02	0.06	0.01	0.02	0.13	0.09	0.07	0.08	0.1	0.098125
RUN OUT	0.11	0.00	0.13	0.30	0.00	0.07	0.03	0.05	0.13	0.08	0.03	0.11	0.04	0.10	0.03	0.06	0.09375
EPILIM	0.09	0.05	0.08	0.04	0.02	0.30	0.04	0.05	0.09	0.03	0.01	0.02	0.01	0.02	0.02	0.03	0.043125
HYPOLIM	0.04	0.5	0.30	0.3	0.04	0.06	0.03	0.02	0.04	0.05	0.03	0.01	0.10	0.37	0.33	0.29	0.18
NITRATE																	
RUN IN	2.35	1.49	1.91	0.063	0.031	0.99	0.7	0.73	1.36	0.03	0.33	4.09	0.139	3.12	1.63	3.36	1.2051625
RUN OUT	2.05	1.97	1.62	0.003	0.037	5.30	0.015	0.44	0.98	0.36	0.31	3.09	0.09	1.23	0.360	0.645	0.9000625
EPIL	1.07	0.70	0.73	0.047	0.015	2.20	1.36	0.95	1.03	0.09	0.30	3.67	0.32	0.594	0.239	0.247	0.831379
HYPOLIM	0.74	0.87	0.61	0.002	0.030	0.99	1.32	1.10	0.99	0.02	0.35	1.3	0.47	0.4673	0.213	0.35	0.6180910
NITRITE																	
RUN IN	0.033	0.070	0.063	0.03	0.33	0.002	0.014	0.013	0.020	0.004	0.065	0.0749	0.0309	0.007	0.032	0.021	0.09575
RUN OUT	0.019	0.042	0.032	0.02	0.40	0.19	0.002	0.040	0.043	0.07	0.074	0.063	0.013	0.009	0.006	0.020	0.0703
EPILIM	0.103	0.040	0.017	0.73	0.44	0.16	0.017	0.004	0.025	0.050	0.041	0.090	0.063	0.041	0.007	0.002	0.1320423
HYPOLIM	0.033	0.012	0.025	0.10	0.14	0.30	0.025	0.007	0.03	0.07	0.020	0.07	0.006	0.007	0.003	0.004	0.0519171
AMMONIA																	
RUN IN	0.143	0.91	0.074	0.13	1.3	0.09	0.391	0.0439	0.0603	0.601	0.12	0.147	0.00095	0.0631	0.006	0.344	0.2733531
RUN OUT	0.159	0.115	0.060	0.193	0.83	0.09	0.243	0.0443	0.109	0.29	0.2949	0.0781	0.0051	0.0004	0.0960	0.196	0.3350041
EPILIM	0.304	0.330	0.403	1.39	0.087	0.09	0.347	0.0003	0.796	4.0	0.1	0.376	0.400	0.57	0.017	0.1259	0.7250625
HYPOLIM	4.07	3.30	3.46	1.11	0.467	0.09	2.11	0.0560	0.402	3.30	0.866	0.075	1.45	1.66	1.80	1.9	1.709175
TKN																	
RUN IN	2.90	1.40	10.37	47.90	4	5.5	4.40	47.04	46.3	30.30	43.22	43.4	30.30	37.36	30.6	36.06	34.2175
RINOUT	2.94	1.40	5.07	30.07	0.93	0.13	1.06	13.0	47.6	34.4	45.02	48.30	27.73	37.03	37.6	37.0	25.816375
EPILIM	2.94	1.40	13.31	0.49	5	4.40	4.40	49.04	40.2	41.46	50.00	50.76	33.05	43.60	35.40	37.1	26.00125
HYPOLIM	5.93	3.35	3.03	1.20	4.5	3.36	0.4	16.0	45.00	36.30	49.30	40.6	33.00	43.40	30.6	34.13	22.420625
TDS																	
RUN IN	370	367	560	301	527	394	439	305	406	415	329	422.67	455.5	430	414.5	327	427.29100
RUN OHUT	303	376.5	603	364	590	359	309	390	481	439	352	390	303	349	333	391	421.94375
EPILIM	305	5770.5	420	366	490	351	312	393	404	342	320	360	334	246.5	400	330	407.5
HYPOLIM	415.5	209	460	310	551	360	337	332	400	313	329	322	301	353	340	316	351.59375
TSS																	
RUN IN	20.5	31	29	347	54	27	4	30	30	4	55.5	47	31.5	30	19	35	30.65625
RUN OUT	34	30	47	163	17	16	1	33	32	21	10	36	23	30	33	12	31.1875
EPILIM	10.5	30	15	7	9.5	1	10	8	1	4	7	23	6	6.5	30	3.5	9.0625
EYPOLIM	13.5	6	33	6	4	3	3	16	6	6	1	9	5	16	20	4	8.84375
CHL. A																	
1 METER	0.139	0.266	0.124	0.124	0.113	0.0010	0.005	0.0012	0.144	0.00	0.190	0.104	0.07	0.05	0.0435	0.0367	0.105073
2 METERS	0.196	0.333	0.3	0.133	0.22	0.0004	0.90	0.0010	0.120	0.100	0.160	0.113	0.099	0.1	0.009	0.0301	0.1043061
3 METERS	0.196	0.094	0.2	0.144	0.116	0.001	0.00	0.0004	0.112	0.003	0.140	0.160	0.077	0.035	0.032	0.0317	0.0315061
4 METERS	0.074	0.060	0.19	0.106	0.130	0.0004	0.074	0.0004	0.002	0.04	0.150	0.10	0.007	0.037	0.035	0.0334	0.077615
5 METERS	0.112	0.084	0.134	0	0.106	0.0012	0.060	0.0004	0.04	0.1	0.17	0.12	0.061	0.031	0.001	0.02	0.0602075

Appendix VIII

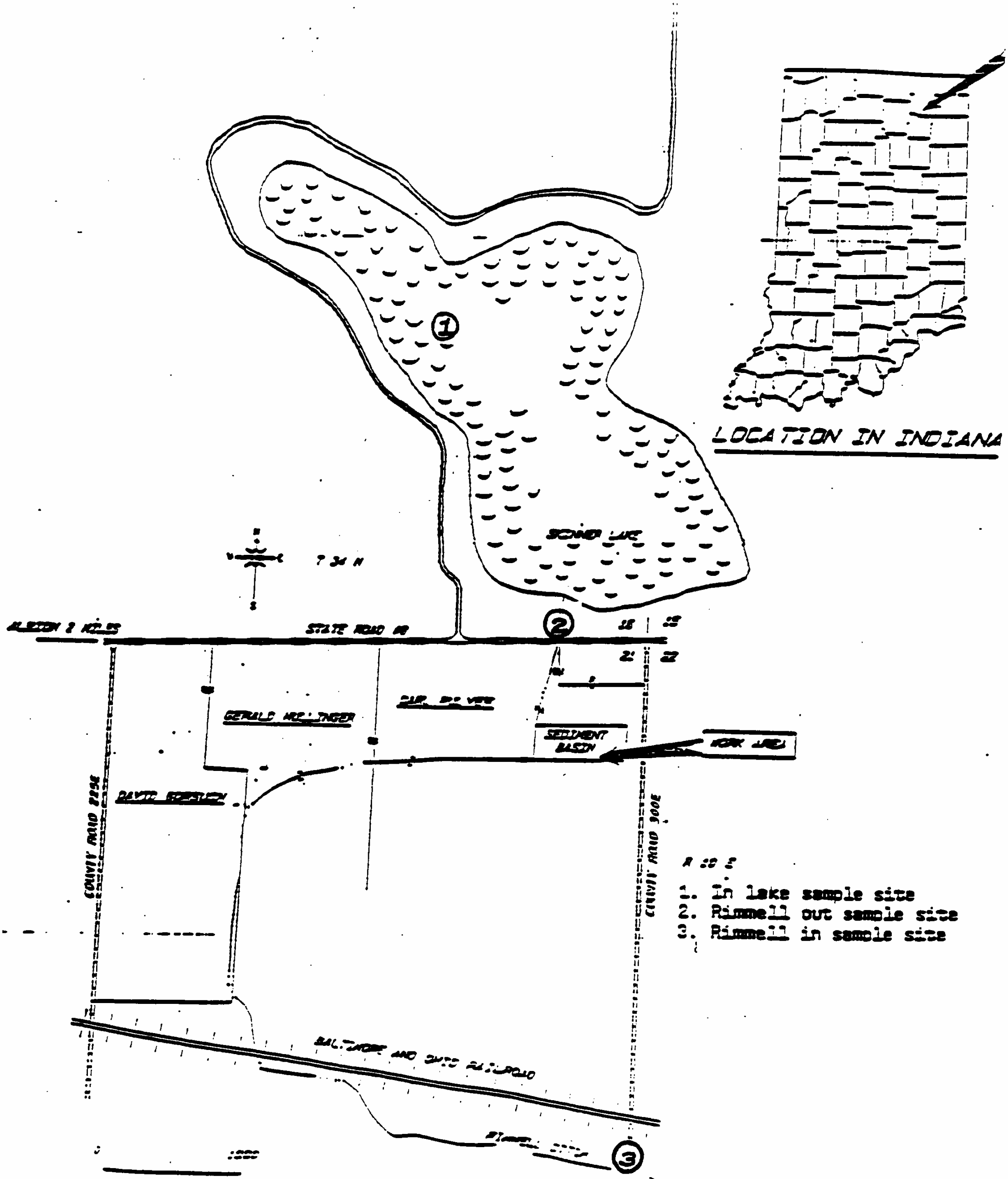
Appendix IX

Secchi disc transparency for Skinner Lake, Noble County, IN, August 1990 through August 1991

Secchi Depth

Sample #	Day #	Date	Depth (m)
1	1	AUG 27	0.7
2	15	SEP 10	0.7
3	36	OCT 1	0.7
4	71	NOV 5	0.7
5	106	DEC 10	0.7
6	152	JAN 25	0.7
7	176	FEB 18	0.7
8	208	MAR 25	0.9
9	243	APR 26	0.9
10	262	MAY 15	2.4
11	276	MAY 29	1.5
12	290	JUN 12	0.8
13	304	JUN 26	0.75
14	319	JUL 11	1
15	332	JUL 24	0.9
16	347	AUG 8	0.9

Appendix X. Study Area and Sampling Sites, Noble County, IN


LOCATION IN INDIANA
SEDIMENT BASIN
COUNTY ROAD 300E
1. In lake sample site
2. Rimmell out sample site
3. Rimmell in sample site

Appendix XI

BonHomme Eutrophication Index for Skinner Lake. Observed values (I-V) calculated from epilimnetic and hypolimnetic samples of June - August 1991 (n=10).

	Parameter and Range	Range Value	Observed	Point Value
I.	Total Phosphorus (mg/L)			
	At least 0.03	1		
	0.04 to 0.05	2		
	0.06 to 0.19	3	X(0.17)	3
	0.20 to 0.99	4		
	Greater than 0.99	5		
II.	Soluble Phosphorus (mg/L)			
	At least 0.03	1		
	0.04 to 0.05	2		
	0.06 to 0.19	3	X(0.1)	3
	0.20 to 0.99	4		
	1.00 or more	5		
III.	Organic Nitrogen (mg/L)			
	At least 0.05	1		
	0.60 to 0.80	2		
	0.90 to 1.90	3		
	2.0 or more	4	X(36.0)	4
IV.	Nitrate (mg/L)			
	At least 0.30	1		
	0.40 to 0.80	2	X(0.5)	2
	0.90 to 1.90	3		
	2.0 or more	4		
V.	Ammonia (mg/L)			
	At least 0.30	1		
	0.40 to 0.50	2		
	0.60 to 0.90	3		
	1.0 or more	4	X(1.1)	4
VI.	Percent oxygen saturation at 5 feet			
	114% or less	0		
	115% to 119%	1		
	120% to 129%	2		
	130% to 149%	3		
	150% or more	4	X	4

Appendix XI (continued).

BonHomme Eutrophication Index for Skinner Lake. Observed values (I-V) calculated from epilimnetic and hypolimnetic samples of June - August 1991 (n=10).

Parameter and Range	Range Value	Observed	Point Value
VII. Percent of Water Column with at least 0.10 mg/L of DO			
28% or less	4		
29% to 49%	3		
50% to 65%	2		
66% to 75%	1		
76% to 100%	0	X(100%)	0
VIII. Secchi Disk Transparency			
5 feet or less	6	X(2.8)	6
Greater than 5 feet	0		
VIV. Light Transmission at 3 feet			
0% to 30%	4	X	4
31% to 50%	3		
51% to 70%	2		
71% or greater	0		
X. Total Plankton from 5 foot Tow (#/L)			
Less than 4,700/L	0		
4,701/L to 9,500/L	1		
9,501/L to 19,000/L	2		
19,001/L to 28,000/L	3		
28,001/L to 57,000/L	4		
57,001/L to 95,000/L	5		
95,001/L or more	10	X(>10^7)	10
Blue-green dominance	5	X	5
XI. Total Plankton from Themocline Tow (#/L)			
Less than 9,500/L	0		
9,501/L to 19,000/L	1		
19,001/L to 47,000/L	2		
47,001/L to 95,000/L	3		
95,001/L to 190,000/L	4		
190,001/L to 285,00/L	5		
285,001/L or more	10	X(>10^7)	10
Blue-green dominance	5	X	5
Population of 950,000 or more			
INDEX VALUE			60

HOOSIER
MICROBIOLOGICAL
LABORATORY

912 West McGalliard Muncie, Indiana 47303-1702 1-317-288-1124

TO: Indiana Department of Natural Resources

FROM: Donald A. Hendrickson
HML, Inc. (Hoosier Microbiological Laboratory)

RE: Chemical Analysis - Skinner Lake Project

DATE: April 21, 1992

Upon your recommendation, we have re-evaluated our testing methods and quality assurance procedures and believe the data presented to Dr. Warnes for the Skinner Lake project are correct. This request came about because of some unusually high values reported for nitrogen and phosphorus species.

We have appreciated the opportunity to serve the state of Indiana, its T by 2000 Lake Enhancement program, and those researchers at Ball State University. We hope we may be of further help on future projects.

Donald A. Hendrickson

Donald A. Hendrickson, Ph.D.
Microbiologist - Owner